The International Journal of Engineering and Science (IJES)
|| Volume || 13 || Issue || 4 || Pages || PP 120-130 || 2024 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Detection of Heavy Metal Levels in Packed and Loose Turmeric Samples in Hyderabad by using ICP-MS Technique

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----------***ABSTRACT***----------
In and around Hyderabad, India, samples of turmeric powder were tested for macro, micro, and heavy metals. The turmeric samples were gathered from open markets in two different ways: branded (packed) samples, identified by numbers 1 to 14, and unbranded (loose) samples, identified by numbers 15 to 30. ICP-MS Technique was used to identify the following elements in these samples: Al, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Ag, Cd, Ba, Pb, Ca, and Mg. The increasing focus on figuring out different macro, micro and heavy metal analyses in order to detect contamination levels and protect public health. However In this work, inductively coupled plasma mass spectroscopy is used to investigate the amounts of heavy metals. The concentrations of Mn, Fe, Al, Ca, Mg were observed to be higher than the recommended limits which the FSSAI had authorized, the study intends to ascertain the level of heavy metals in commonly used spices sold at stores and open markets, as well as to estimate health hazard concerns associated with heavy metal intake through spice consumption has given the significance of this research and its significant connection to human health.

KEYWORDS;- *ICP-MS, FSSAI, heavy metals, macro metals, micro metals*

Date of Submission: 25-04-2024 Date of acceptance: 02-05-2024

I. INTRODUCTION

Heavy metals are necessary and harmful, their frequent contamination of food has drawn attention from researchers and studies during the past 10 years (Al-Eed et.al 2002). Environmental pollution is the main factor contributing to heavy metal contamination in the food chain (K.I. Kasozi et.al 2021) . The amount of heavy metals added to food throughout its manufacture, shipping, processing, and fortification determines how much is present in each individual food (M. Neyestani et.l 2020) . Due to the vital or dangerous impacts that trace metals can have on human health, it is imperative that we comprehend the amount of these metals in food (E.I. Brima et.al 2017) . Even in minute concentrations, heavy metals are not necessary for human health, and their bioaccumulation makes them hazardous. The steady rise in a chemical's concentration within a biological organism is known as bioaccumulation, as opposed to chemical concentration in the environment (D. Savoca et.al 2021). Regular ingestion of heavy metal-contaminated spices can lead to metal buildup in the body's organs. (Z.Z. Aberieet.al 2021).. Because heavy metal accumulation can pose short-, medium-, and long-term health hazards, it is recommended to regularly evaluate these contaminants attentively (H. Mubeen et.al 2009). Copper, iron, and zinc are examples of basic metals that are necessary for normal body development but excessive concentrations are dangerous and seriously endanger the health of people and animals (A. Marian et.al 2010). Certain metals, including lead and cadmium, are dangerous even at extremely low quantities (Inam et.al 2013) Excessive levels of heavy metals have an adverse effect on human health and can cause premature labor, mental retardation in children, and illness in foetuses (Mubeen et.al 2000). Considerable study is needed to solve this issue because these heavy metals may be harmful to human health, including neurological abnormalities, growth retardation, and immune system deficiencies (Sattar et.al 1989). Spices are dried plant parts that are added to food as dietary components to improve its flavor, color, and aroma (Singh et.al 2001). When heavy metal-contaminated spices are added to food to improve its flavor, these metals may accumulate in human organs and have negative health effects. Through the food chain, the accumulation of potentially dangerous

metals might subsequently affect physiological processes in humans (Verpoort et.al 2003). Each spice has a different amount of heavy metals according on the growing environment, agronomic techniques, and processing. (Cicero N. et.al 2022). Furthermore, heavy metal contamination is increasingly being caused by economically driven indulgence. (Chachan S et.al 2021). The primary analytical techniques used for evaluating the elements in spices and condiments are inductively coupled plasma and atomic absorption/emission modalities (ICP-MS). (Tokalıoğlu S et.l 2018), (Russom E et.l 2019), (Reinholds I et.al 2017). This study's primary goal is to determine the amount of heavy metals, macro elements and microelements The elements (Al, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Ag, Cd, Ba, Pb, Ca, and Mg) found in common spices that were purchased at neighborhood markets in Hyderabad. Additionally, a comparison was made between the studied heavy metal level and the FSSAI-approved standard level.

II. MATERIAL AND METHODS

A variety of 500 gram samples of turmeric powder both branded and unbranded were gathered from various locations in the super markets and open markets. These samples were then sealed in ziplock bags and tested with ICP-MS testing in the State Food Laboratory Nacharam, Hyderabad. Locations of various samples that has been collected are listed in the table given below.

Table 1: Naming & Location of the Collected Branded and Unbranded Turmeric Samples

Branded Samples		**Unbranded Samples (Loose Turmeric Powder From Open Markets)**	
Sample No	**Location**	**Sample No**	**Location**
1	Saroornagar	15	Malakpet
2	Osmangunj	16	Miyapur
3	Dmart Champapet	17	Maddanapet mandi Saidabad
4	Saroornagar	18	Erragadda
5	Dilshuknagar	19	Open market roadside
6	Heritage fresh Saidabad	20	L.B Nagar
7	Dmart Champapet	21	Pragathi Nagar
8	Ashoknagar	22	Openmarket
9	Dmart Champapet	23	Nallagandla, Lingampally
10	Dmart Champapet	24	BegumBazar
11	Heritage fresh Saidabad	25	BegumBazar
12	Honey Rostea Saidabad	26	Osmangunj
13	Heritage fresh Saidabad	27	Dilshuknagar
14	Heritage fresh Saidabad	28	Kukatpally
		29	Secunderabad
		30	Secunderabad

Sample Preparation:

The microwave digestion system must be used to prepare the food samples for testing. Water is used to dilute the digested solution. The calibration solutions' nitric acid concentrations have to be comparable to the test solution's final nitric acid concentrations.

METHODOLOGY : The Inductively Coupled Plasma Mass Spectrometry (ICP-MS) system with cross flow nebulizer was used to analyze the samples for several elements, and the standard operating procedure outlined in the Perkin Elmer NEXION 2000 manual was adhered to. Multi-elemental standards were used to analyze in the the digested samples Argon gas is used to check the purity at a operating pressure of 3200 VA, and helium is used for collision cell to check the high purity, high purity nitric acid and high purity Hydrochloric acid is used and 30% of hydrogen peroxide is used An HNO3 tuning solution containing 0.5% HCL is used to adjust the

ICP-MS in order to assess the purity of trace elements. Establishing Work Standards and Prepare multi element working standards by diluting the intermediate standard with 5% HNO3 – 0.5% HCl.

Table1. Maximum Heavy Metal Limit Values in Turmeric Powder

S.No.	The Heavy Metal's Name	FSSAI Permissible Limit (PPM) (PPM)
1	Chromium	5
2	Manganese	5
3	Iron	5
4	Nickel	5
5	Arsenic	0.1
6	Silver	0.1
7	Cadmium	0.1
8	Lead	10
9	Zinc	25
10	Selenium	0.1
11	Barium	0.1
12	Copper	5
13	Aluminium	5
14	Calcium	10
15	Magnesium	10

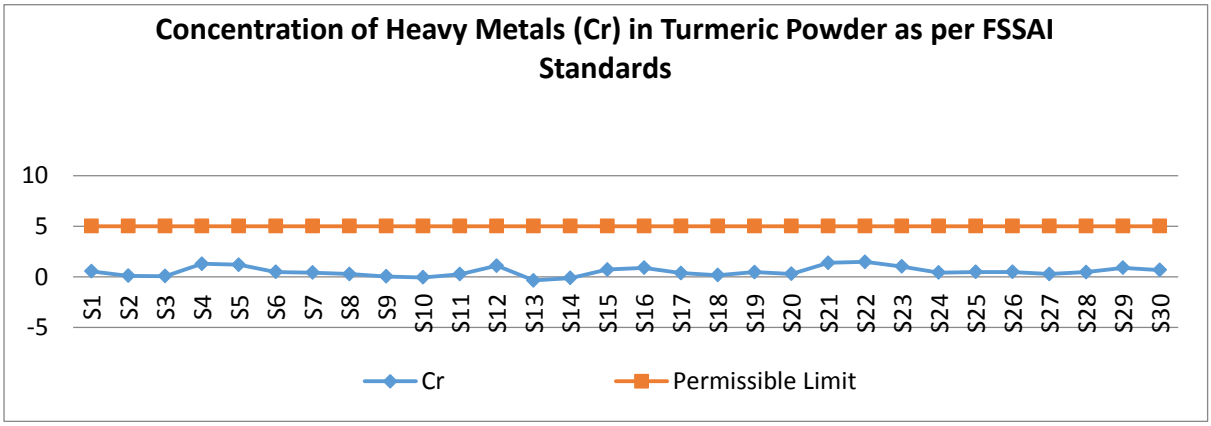

Figure 1. The highest concentration of heavy metals (Cr) in thirty samples of powdered turmeric.

Chromium (Cr) : It has been determined that all of the thirty samples that were examined falls within the allowable limit. As a result, none of the spice samples included in the study are harmful to health; instead, Considering the various exposure sources, it is believed that heavy metal levels in turmeric powder should be closely watched.

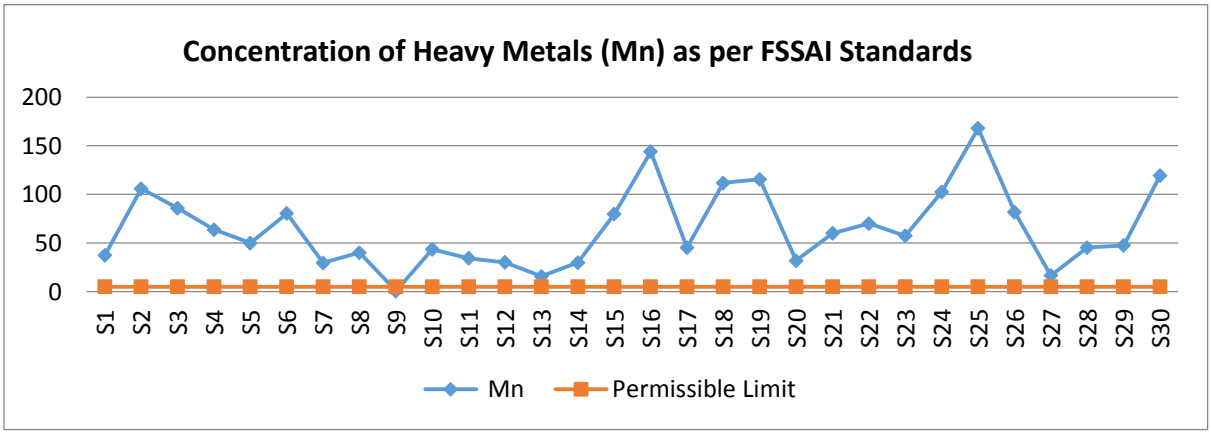

Figure 2. Maximum Concentration of Heavy Metals (Mn) in 30 thirty samples of powdered turmeric.

Magnesium (Mn) : All thirty of the examined samples with the exception of sample no nine have been found to have Mn concentrations that exceed the allowable limit according to FSSAI standards.

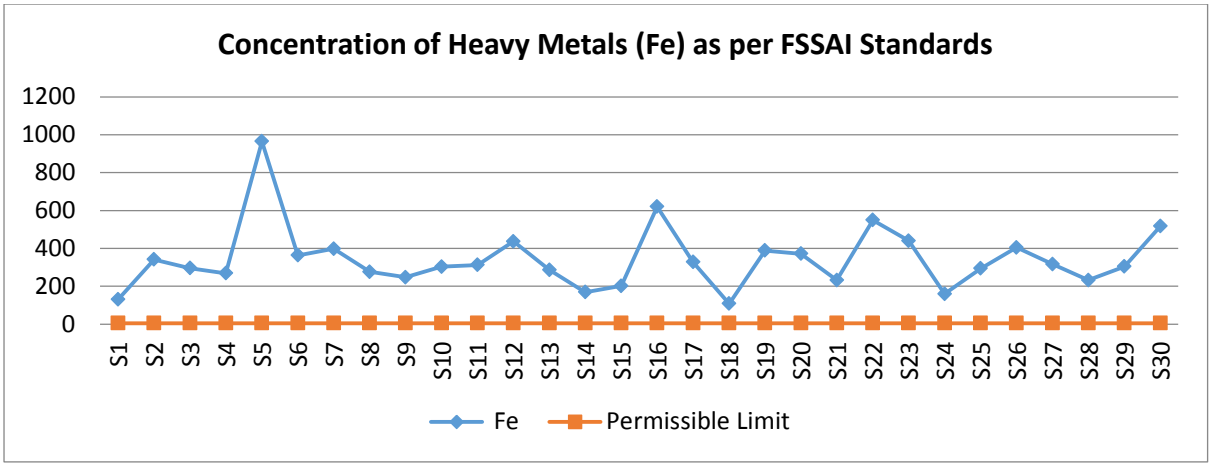

Figure 3. Maximum Concentration of Iron (Fe) in 30 samples of powdered turmeric.

Iron (Fe) : It has been found that all of the thirty samples had a concentration of iron that exceeded the FSSAI Standard's recommended limits.

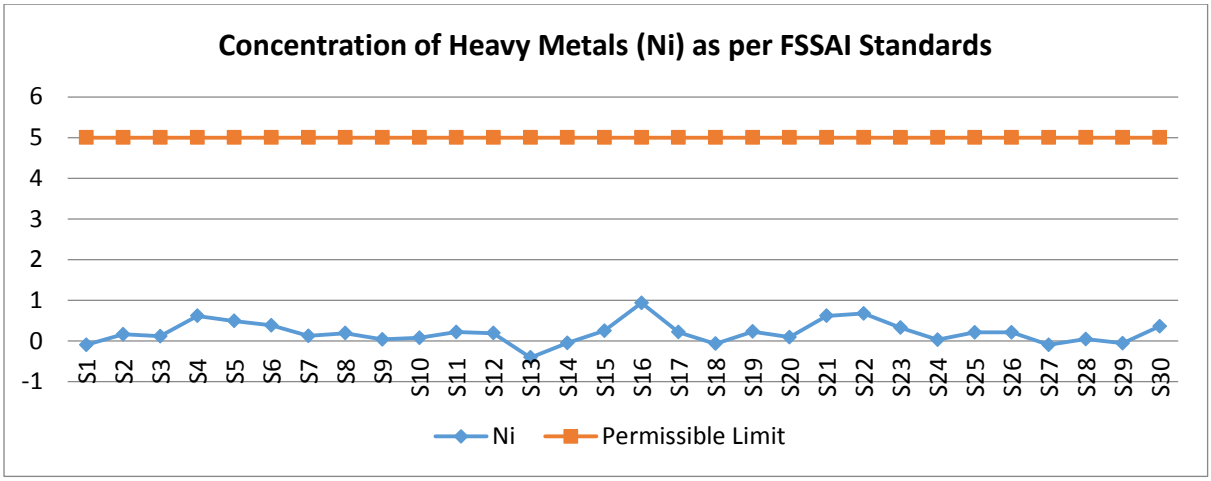

Figure 4. Maximum Concentration of Heavy Metals (Ni) in 30 Turmeric Powder samples.

Nickel (ni) : It has been noted that all of the thirty samples is below the allowable limit as specified by the FSSAI Standards.

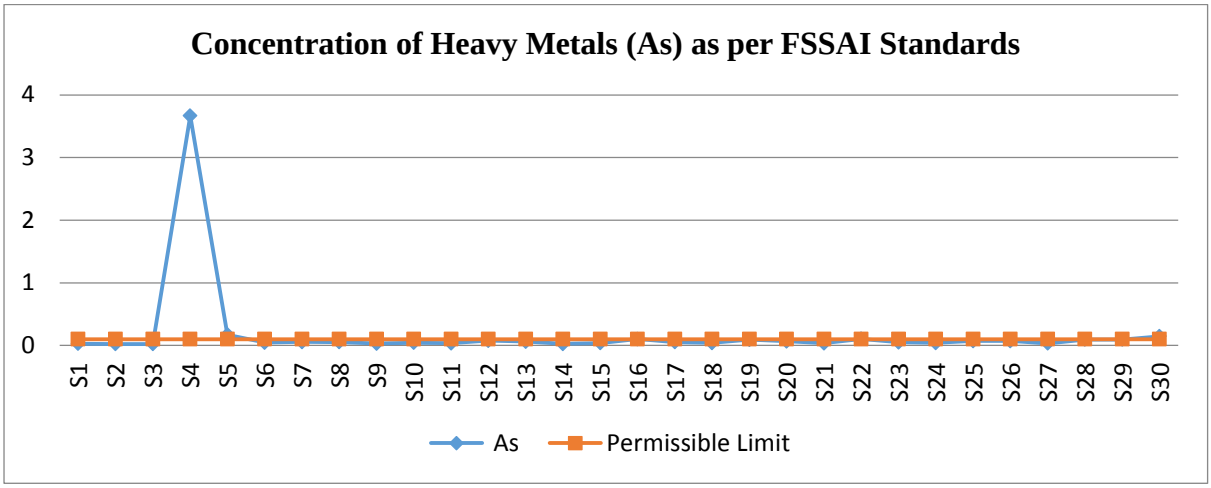

Figure 5. Maximum Concentration of Heavy Metals (As) in 30 thirty samples of powdered turmeric.

Arsenic (As) : It has been noted that only two samples S3 and S5 out of thirty samples is below the allowable limit as specified by the FSSAI Standards.

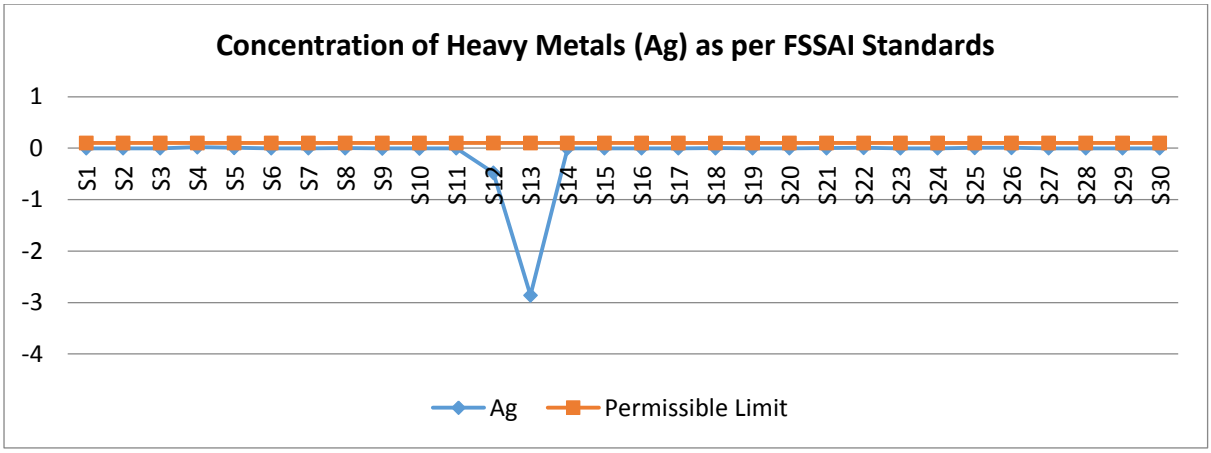

Figure 6. Maximum Concentration of Heavy Metals (Ag) in 30 thirty samples of powdered turmeric.

Silver (Ag) : It has been noted that each of the thirty samples is below the allowable limit as specified by the FSSAI Standards

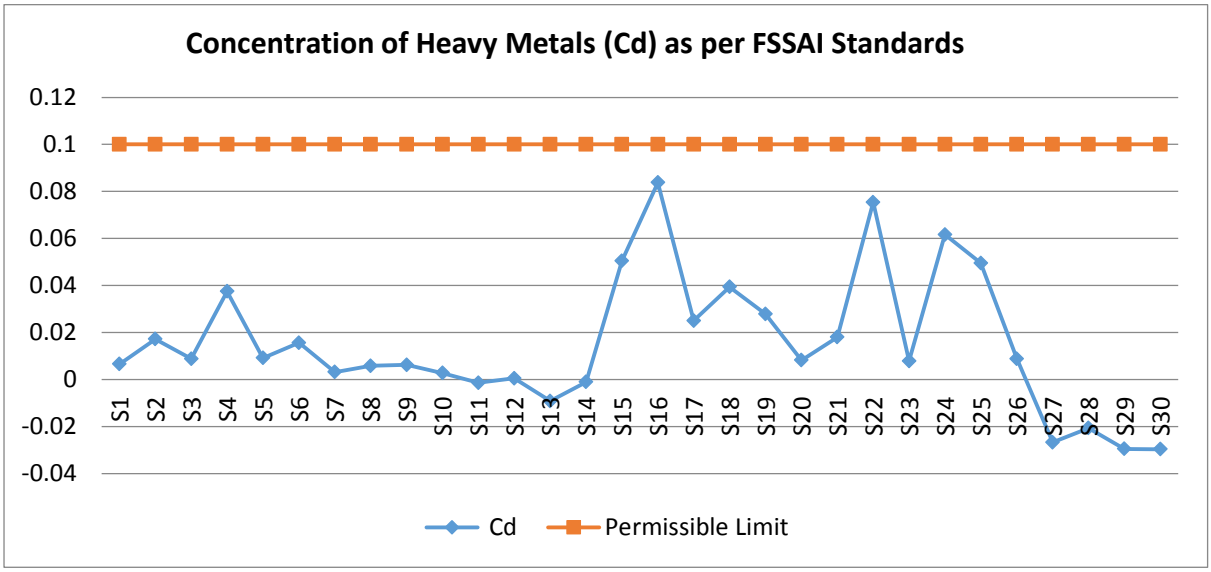

Figure 7. Maximum Concentration of Heavy Metals (Cd) in 30 thirty samples of powdered turmeric.

Cadmium (Cd) : It has been noted that each of the thirty samples is below the allowable limit as specified by the FSSAI Standards

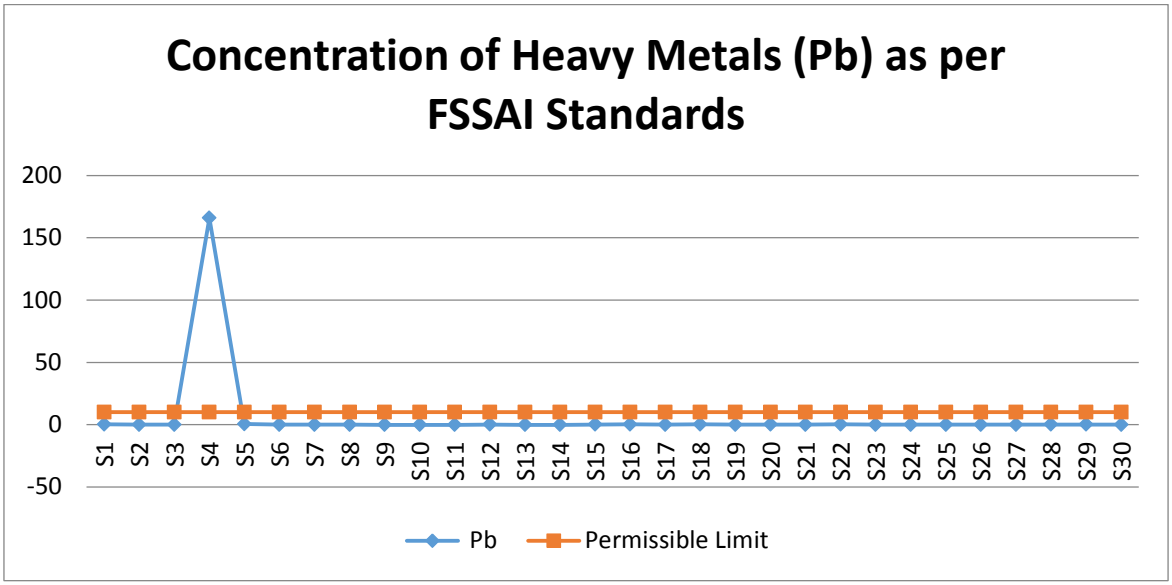

Figure 8. Maximum Concentration of Heavy Metals (Pb) in 30 thirty samples of powdered turmeric.

Lead (Pb) : It has been noted that only one sample S4 out of the thirty samples is below the allowable limit as specified by the FSSAI Standards

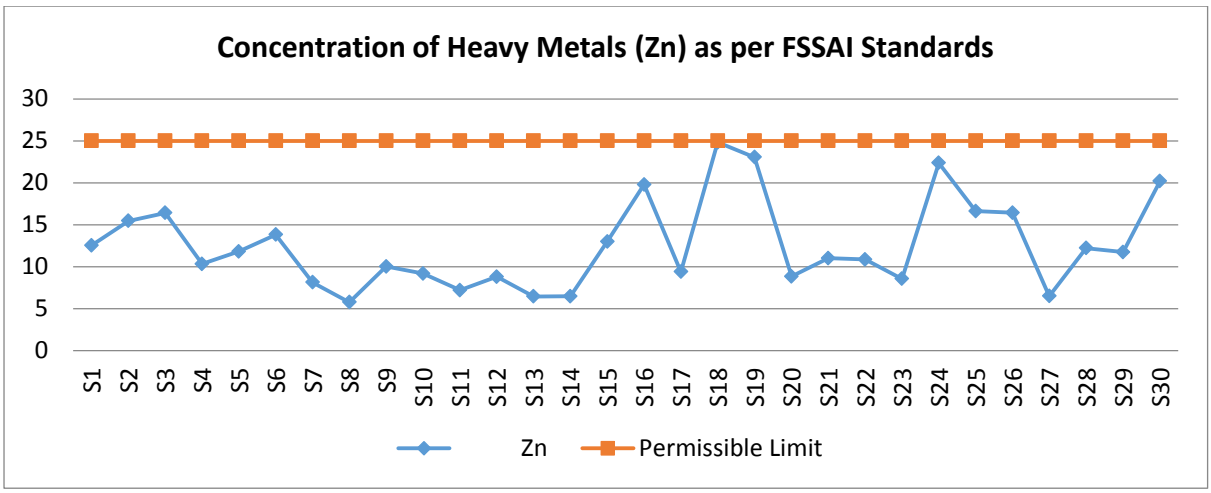

Figure 9. Maximum Zinc Concentration of Heavy Metals in 30 thirty samples of powdered turmeric.

Zinc (Zn) : It has been noted that each of the thirty samples is below the allowable limit as specified by the FSSAI Standards

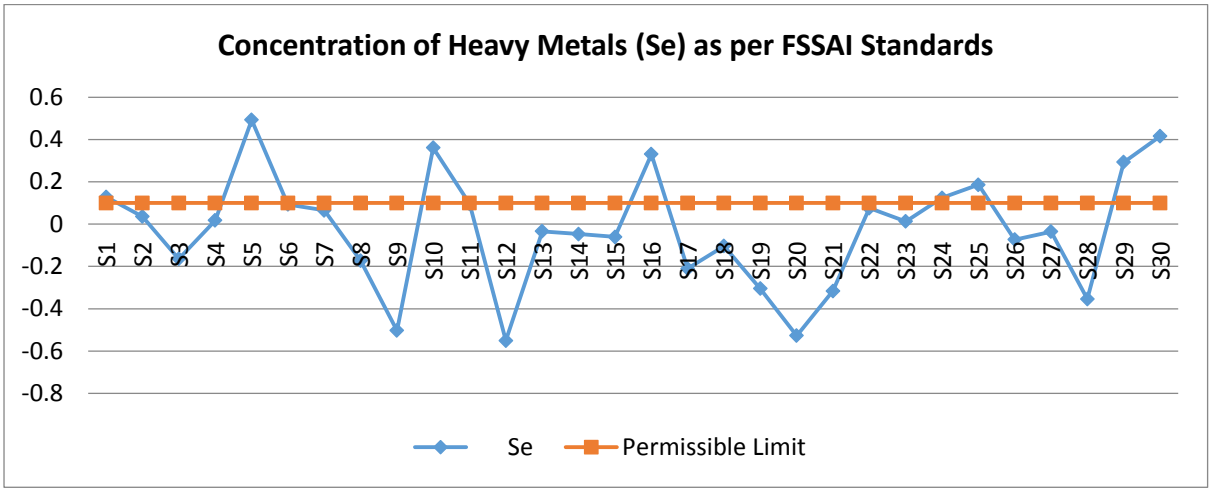

Figure 10. Maximum Concentration of Heavy Metals (Se) in 30 thirty samples of powdered turmeric.

Selinium (Se) : It has been noted that only three sample no 1, 24,25 out of the thirty samples is above the allowable limit as specified by the FSSAI Standards

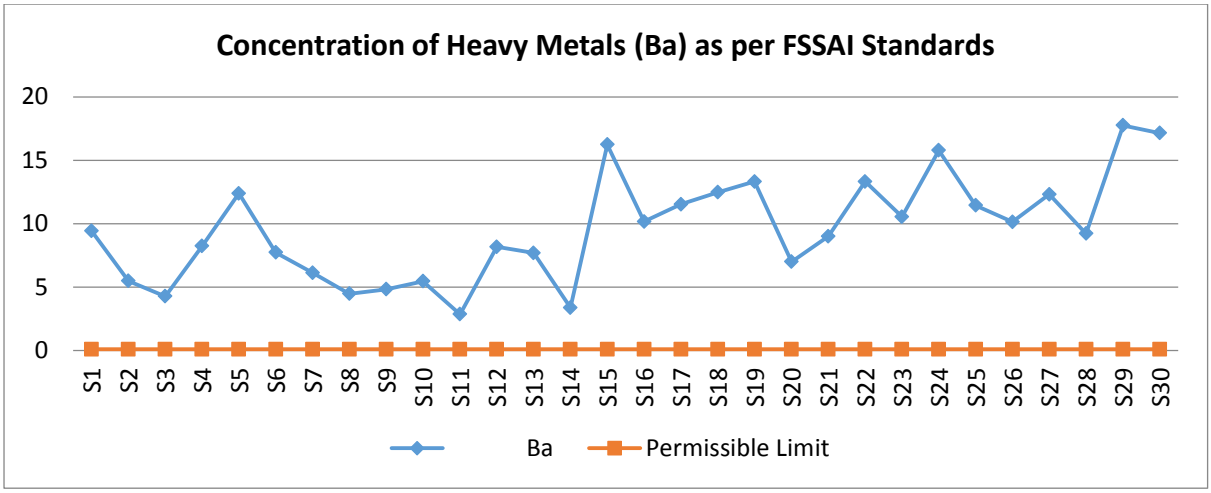

Figure 11. Maximum Concentration of Heavy Metals (Ba) in 30 thirty samples of powdered turmeric.

Barium (Ba) : It has been found that all of the thirty samples had a concentration of barium that exceeded the FSSAI Standard's recommended limits.

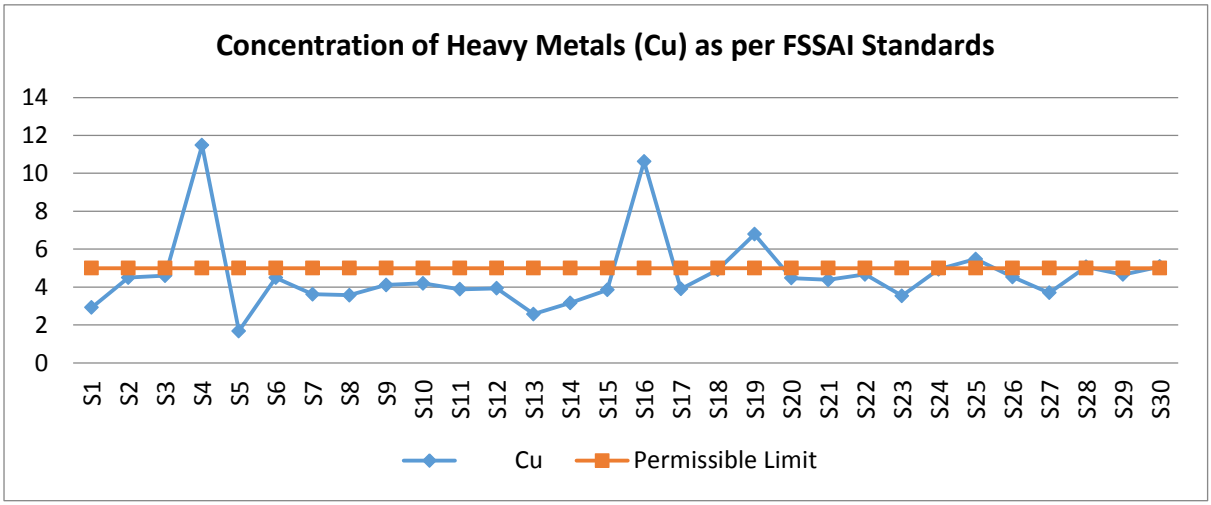

Figure 12. The highest concentration of copper (Cu) in thirty samples of thirty samples of powdered turmeric.

Copper(Cu) : It has been noted that only five samples no 4, 16,19,25,28 out of the thirty samples is above the allowable limit as specified by the FSSAI Standards

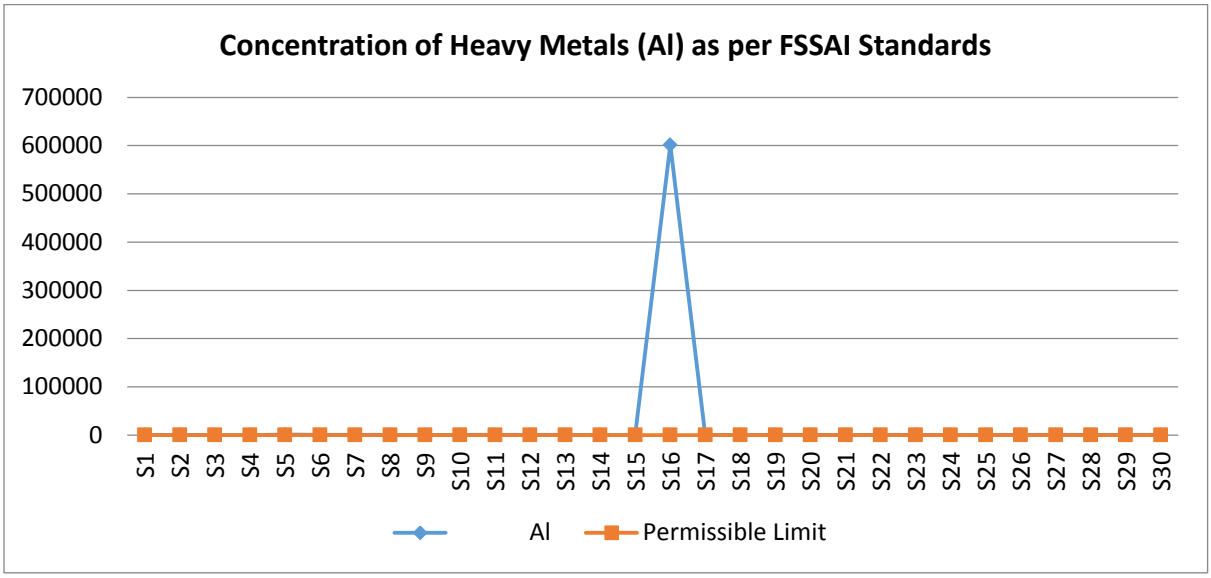

Figure 13. Maximum Concentration of Heavy Metals (Al) in 30 thirty samples of powdered turmeric.

Aluminium (Al) : It has been found that all of the thirty samples had a concentration of aluminium that exceeded the FSSAI Standard's recommended limits.

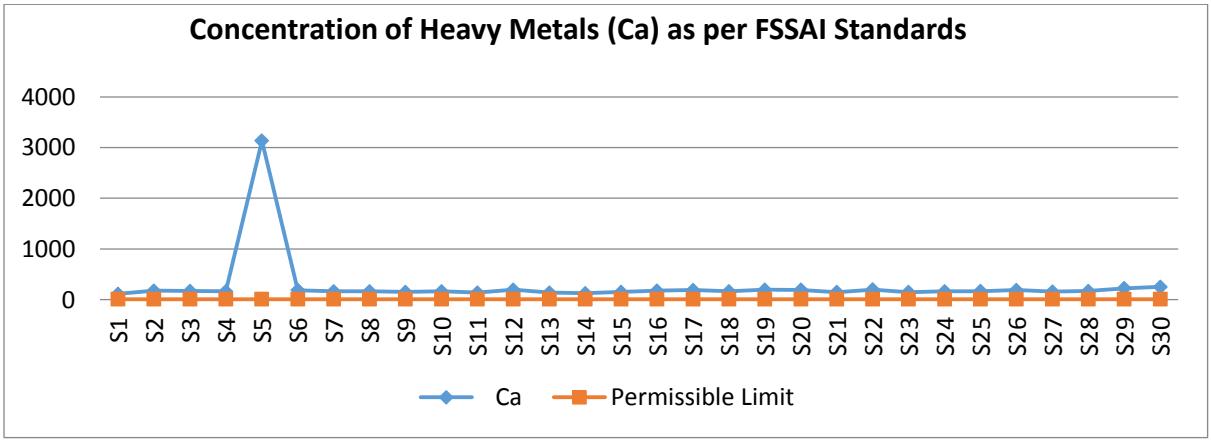

Figure 14. Maximum Concentration of Heavy Metals (Ca) in 30 thirty samples of powdered turmeric.

Calcium (Ca) : It has been found that all of the thirty samples had a concentration of calcium that exceeded the FSSAI Standard's recommended limits.

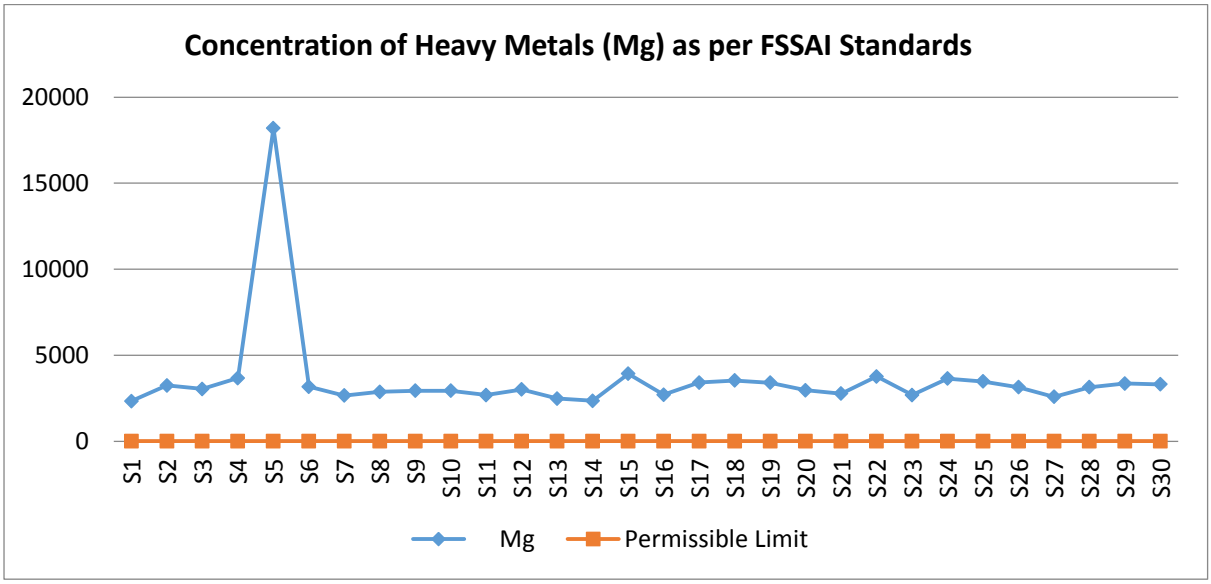

Figure 15. Maximum Concentration of Heavy Metals (Mg) in 30 thirty samples of powdered turmeric.

Magnesium (Mg) : It has been found that all of the thirty samples had a concentration of magnesium that exceeded the FSSAI Standard's recommended limits.

III. RESULTS AND DISCUSSIONS

The thirty samples of turmeric that were analyzed for contamination with heavy metals, macro and micro elements, and their potential effects on human health have produced a wide range of results, including higher amounts than those recommended by the Food Safety and Standards Authority of India (FSSAI). The ICP-MS results clearly indicated that dangerous heavy metals like manganese (Mn), ferrous (Fe), barium (Ba) and aluminum (Al) are present in very higher concentrations as shown in the Graph given. Only one or two samples were high in arsenic (As) and selenium (Se) whereas five to six samples were high in copper (Cu). All the thirty samples i.e., branded and unbranded packages of turmeric were free of chromium (Cr), nickel (Ni), cadmium (Cd), lead (Pb), silver (Ag) and zinc (Zn).

Only one sample in lead has been identified to be more with its concentration of 165.88377 PPM Because of its high toxicity, lead (Pb) is a cumulatively toxic material that damages many human body systems, particularly in young children. (G.J. Brewer et.,al 2020). Pb poisoning concentrates in the brain, bones, blood, kidneys, thyroid gland, and blood, impairing thyroid gland function and causing mental retardation in children. Pb metal is thought to be a direct competitor of Ca at protein absorption sites in the small intestine's mucous membrane. (N. Singh et.,al 2018). Macro elements such as calcium and magnesium are also in very high concentrations than the required amounts. The FSSAI permissible limit for Cr contamination was 5PPM and all the samples of turmeric had chromium from the range of 0.05 to 1.5PPM which are considered supposedly safe for human consumption. The permissible limits for Mn and Fe were 5PPM each but the values in the present study ranged from 0.6 to 143PPM and 160 to 543PPM respectively which were too high. Research has shown evidence that higher amounts of manganese and ferrous would cause neurotoxic effects in children and adults (Albretsen, 2006; Wasserman et al., 2006; Wessling-Resnick, M., 2017). The permissible limits for Ni and Cu were 5PPM each and the values from the study ranged from 0.03 to 0.61PPM and 2.9 to 4.9PPM respectively, but five samples (sample 4, 16, 19, 25 and 30) showed higher concentrations of Cu, which ranged from 5.1 to 11.5PPM. Higher amounts of copper consumption led to liver, kidney, eyes and nerves damage (Bjorn et al., 2023; Araya et al., 2003). Ag and Cd permissible limits were 0.1PPM each and all the samples in the present study were within the range from 0.00035 to 0.006PPM and 0.0005 to 0.006PPM respectively. Pb and Zn were also within their permissible limits of 10PPM and 25PPM respectively, which ranged from 0.01 to 0.29PPM and 5.7 to 24.8PPM respectively. Only one sample (sample 4) had a very high amount (165.88PPM) of lead which could cause lead poisoning to animals and humans. In a similar study, (Paranthaman et al., 2021), worked on a quantitative method for finding lead chromate adulteration levels in turmeric. As and Se are acceptable upto a limit of 0.1PPM each as per the FSSAI standards and the present study results ranged from 0.02 to 0.1PPM and 0.01 to 0.1PPM respectively but very few numbers of samples have shown a bit higher value for As (sample 4, 5 and 30) and few numbers of Se samples (sample 1, 5, 10, 16, 24, 25, 29 and 30) were higher than the permissible limits. Guha Mazumder., 2008 and (Ahmed et al.,2016) have mentioned in their studies that prolonged exposure to arsenic pollution can lead to dangerous diseases like cancer and brain damage. The heavy metal Ba is not supposed to be more than 0.1PPM in foods and spices but the present study samples all had a

very high concentrations of Ba ranging from 3.3 to 7.7PPM which is too much. Barium carbonate is a chemical component used in making rat poisons. Barium pollution leads to cardiac diseases and death. The permissible limits for aluminum were 5PPM and the Al concentrations of the samples in the present study results ranged from 133 to 1065PPM which can be considered extremely high and toxic for the public who consumed these supposed turmeric powders daily. In larger doses, aluminum can be neurotoxic (Lawrence et al., 2012). Al may be the source of neurofibrillary tangles and amyloid senile plaques in brain tissue associated with Alzheimer's disease (AD). Chronically consuming too much aluminum can cause an imbalance in the body and impair one's capacity for memory, reasoning, and cognitive function. (Chen, J et.l). It is inevitable that everyday use will result in serious ailments like Parkinson's disease, Alzheimer's disease, and bone abnormalities. Microelements Ca and Mg are permissible up to 10PPM each but in the present study their concentrations were extremely high which ranged from 112 to 3133PPM and 2332 to 18203PPM (Graphs) indicating the adulteration with chalk powder in all the samples. Fe is an essential component. Along with other components like hemoglobin and ferrodoxin, Fe is essential for metabolism. Fe increases the oxidation of fat, protein, and carbs to control body weight, an important aspect of several illnesses (diabetes), (S. Kumar et al., 2021). All the samples that has been tested has shown higher concentrations of Fe in all the samples indicating Diabetes, heart failure, and cirrhosis can also be brought on by an overabundance of iron. Symptoms of iron poisoning that appear early include nausea, vomiting, and stomach pain (J. Briffa et al., 2020). Hence from the above results it can be clearly concluded that the turmeric powder sample being marketed around the city of Hyderabad are all adulterated to some extent with dangerous heavy metals, trace elements and microelements. Quality and public health are compromised in rapidly growing food demand and human needs.

IV. CONCLUSION

Based on the findings, it can be said that, with the exception of a small number of metals, most of the spices sold at Hyderabad's local market are not highly polluted with heavy metals. Since the daily intake of spices is quite small, there are no negative consequences however, consumers may be at risk for health problems if they use them excessively. Regularly checking spice samples is also advised.

REFERENCE

[1] G.J. Brewer, A.S. Prasad, Essential and Toxic Trace Elements and Vitamins in Human Health, Academic Press, 2020.

[2] N. Singh, A. Kumar, V.K. Gupta, B. Sharma, Biochemical and molecular bases of lead-induced toxicity in mammalian systems and possible mitigations, Chem. Res. Toxicol. 31 (10) (2018) 1009–1021.

[3] Al-Eed, M. A., F. N. Assubaie, M. M. El-Garawany, H. El-Hamshary, and Z. M. El-Tayeb.(2002). "Determination of heavy metal levels in common spices."J ApplSci, vol 17, pp 87-98.2

[4] K.I. Kasozi, E.O. Otim, H.I. Ninsiima, G. Zirintunda, A. Tamale, J. Ekou, G.H. Musoke, R. Muyinda, K. Matama, R. Mujinya, An analysis of heavy metals contamination and estimating the daily intakes of vegetables from Uganda, Toxicol. Res. Appl. 5 (2021) (2397847320985255).

[5] M. Neyestani, P. Shavali-Gilani, M. Fesahat, E. Molaee-Aghaee, N. Shariatifar, The effect of food processing on the amount of trace elements and their bioavailability: a review, J. Food Saf. Hyg. 6 (2) (2020) 53–66.

[6] E.I. Brima, Toxic elements in different medicinal plants and the impact on human health, Int. J. Environ. Res. Public Health 14 (10) (2017) 1209.

[7] D. Savoca, A. Pace, Bioaccumulation, biodistribution, toxicology and biomonitoring of organofluorine compounds in aquatic organisms, Int. J. Mol. Sci. 22 (12) (2021) 6276.

[8] Z.Z. Aberie, F.Z. Sallilh, M. Medfu Tarekegn, Investigation of heavy metals in selected local spices consumed in Ethiopia, Cogent Food Agric. 7 (1) (2021) 1917091.

[9] H. Mubeen, I. Naeem, A. Taskeen, Z. Saddiqe, Investigations of heavy metals in commercial spices brands, N. Y. Sci. J. 2 (5) (2009) 20–26.Marian and C. OpokuAmoako.(2010). "Heavy metal content of some common spices available in markets in the Kumasi metropolis of Ghana."Am J SciInd Res, vol 2, pp 158-63.

[10] Inam, Farhin, SujataDeo and N. Narkhede. (2013). "Analysis of minerals and heavy metals in some spices collected from local market." J. of.Phar.andBio.Sci, vol 2, pp 40-43.

[11] Mubeen, Hifsa, IsmatNaeem, AbidaTaskeen, and ZebSaddiqe.(2009). "Investigations of heavy metals in commercial spices brands."New York Science Journal, vol 5, pp 1554-2000.

[12] Sattar, Abdus, Mohammad Wahid, and Shahid Khan Durrani.(1989). "Concentration of selected heavy metals in spices, dry fruits and plant nuts."Plant Foods for Human Nutrition, vol 3, pp 279-286.

[13] Singh, K.P., D. Mohan, S. Sinha and R. Dalwani. (2004).“Impact assessment of treated/untreated waste water toxicants discharged by sewage treatment plants on health.” agricultural and environmental quality in the waste water disposal areas. Chemosphere, vol 55, pp227-255.

[14] Verpoort, R.; Contin, A.; Memelink, J. Biotechnology for the production of plant secondary metabolites. Phytochem. Rev. **2002**, 1,13–25. [CrossRef]

[15] Cicero N, Gervasi T, Durazzo A, Lucarini M, Macrì A, Nava V, Gia- rratana F, Tardugno R, Vadalà R, Santini A (2022) Mineral and microbiological analysis of spices and aromatic herbs. Foods 11:548. https://doi.org/10.3390/foods11040548

[16] Chachan S, Kishore A, Kumari K, Sharma A (2021) Trends of food adulteration in developing countries and its remedies. Food Chem: Role Additives, Preserv Adulteration. https://doi.org/10.1002/9781119792130.ch6

[17] Tokalıoğlu S, Çiçek B, İnanç N, Zararsız G, Öztürk A (2018) Multi-variate statistical analysis of data and ICP-MS determination of heavy metals in different brands of spices consumed in Kayseri. Turkey Food Anal Methods 11:2407–2418. https://doi.org/10. 1007/s12161-018-1209-y

[18] Russom E, Kfle G, Asgedom G, Goje T (2019) Heavy metals con- tent of spices available on the market of Asmara. Eritrea Eur J Nutr Food Saf 11:156–163. https://doi.org/10.9734/EJNFS/2019/v11i330158

[19] Reinholds I, Pugajeva I, Bavrins K, Kuckovska G, Bartkevics V (2017) Mycotoxins, pesticides and toxic metals in commercial spices and herbs. Food Addit Contam Part B 10:5–14. https:// doi.org/10.1080/19393210.2016.1210244
[20] Albretsen, J., 2006. The toxicity of iron, an essential element. Vet. Med. 101 (2), 82–90 -Bonner Springs Then Edwardsville.
[21] Wasserman, G.A., Liu, X., Parvez, F., Ahsan, H., Levy, D., Factor-Litvak, P., Kline, J., van Geen, A., Slavkovich, V., Lolacono, N.J., Cheng, Z., Zheng, Y., Graziano, J.H., 2006. Water manganese exposure and children's intellectual function in Araihazar, Bangladesh. Environ. Health Perspect. 114 (1), 124–129. doi:10.1289/ehp.8030.
[22] Wessling-Resnick, M., 2017. Excess iron: considerations related to development and early growth. Am. J. Clin. Nutr. 106 (Supplement 6), 1600S–1605S. doi:10.3945/ajcn.117.155879.
[23] Bjorn P, Zietz BP, Dieter HH, et al. Epidemiological investigation on chronic copper toxicity to children exposed via the public drinking water supply. Sci Total Environ 2003; 302:127– 44. 22.
[24] Araya M, Olivares M, Pizarro F, Gonzalez M, Speisky H, Uauy R. Gastrointestinal symptoms and blood indicators of copper load in apparently healthy adults undergoing controlled copper exposure. Am J Clin Nutr 2003; 77:646 –50.
[25] Paranthaman, R., Moses, J., Anandharamakrishnan, C., 2021. Development of a method for qualitative detection of lead chromate adulteration in turmeric powder using Xray powder diffraction. Food Control 126, 107992.
[26] Guha Mazumder DN. Chronic arsenic toxicity & human health. Indian J Med Res 2008;128:436-47.
[27] Ahmed MK, Shaheen N, Islam MS, Habibullah-Al-Mamun M, Islam S, Islam MM, et al. A comprehensive assessment of arsenic in commonly consumed foodstuffs to evaluate the potential health risk in Bangladesh. Sci Total Environ 2016; 544:125-33.
[28] Lawrence MS, Mia V, Gallo, Katsi C. Whats not to eat food adulteration in the context of human biology. American journal of human biology. 2012;24(2):139-148.
[29] Chen, J., Chen, F., Wang, L and Chen, S. (2011a). Studies on Determination of 19 Inorganic Elements in Gynostemma Pentaphyllum. Food Res. Dev. 32 (05), 131-133.
[30] Phukan M, Sahariah M, Sahu S. Study of Curcumin Content and Adulterants Present in Different Marketing Brands of Turmeric Powder, Curr Trends Pharm Res,2022;8 (2): 35
[31] S. Kumar, T. Behl, M. Sachdeva, A. Sehgal, S. Kumari, A. Kumar, G. Kaur, H.N. Yadav, S. Bungau, Implicating the effect of ketogenic diet as a preventive measure to obesity and diabetes mellitus, Life Sci. 264 (2021), 118661.
[32] J. Briffa, E. Sinagra, R. Blundell, Heavy metal pollution in the environment and their toxicological effects on humans, Heliyon 6 (9) (2020), e04691.